GEOGRAPHIC DISTRIBUTION AND DISPERSAL OF SOME RECENT SHALLOW-WATER MARINE OSTRACODA

JAMES W. TEETER

Department of Geology, The University of Akron, Akron, Ohio 44304

ABSTRACT

Several species of Recent shallow-water tropical marine ostracodes have achieved interoceanic distribution. Passive dispersal of these marine ostracodes on feathers and muddy feet of migratory shore birds, a process often cited for the distribution of freshwater ostracodes, is unlikely because of the water depth in which these ostracodes live, their lack of a dessication-resistant egg, and the lack of correspondence between their distribution and migratory bird flyways. Other means of ostracode dispersal cited in the literature, including transport in the intestinal tracts of birds and fish, and transport by wind, are also considered unlikely.

Some of the ostracodes considered here have been found on tropical floating marine algae. Such drifting algae may account for the transoceanic dispersal of associated ostracodes within tropical latitudes. Interoceanic dispersal of algal-associated tropical ostracodes would probably be prevented at higher latitudes by colder water temperatures. Man may inadvertently assist interoceanic dispersal through the Suez and Panama Canals by the use of water ballast during ship passage. The greater number of ostracodes in common between the Indo-Pacific Ocean and the Caribbean Sea suggests that Panama may be the more frequently used route. The majority of the ostracodes with a known fossil record appear to have dispersed from the Indo-Pacific area.

INTRODUCTION

In recent years the academic community has expressed a great deal of concern at the prospect of construction of a sea-level canal across Central America and the effect of the resultant inferred biological migrations (Rubinoff, 1968; Boffey, 1971). Difficulties in assessing the biological effects of such a canal stem from the fact that few studies exist on the dispersal of various types of organisms through similar canals, and on the presence of physical and chemical barriers that may at least partially restrict the migration of marine organisms along existent canals. This restriction presumably would not exist in the newly proposed sea-level canal, because of its more uniform conditions.

Dispersal may be accomplished by active means, in which the organism is naturally mobile, or by passive means, in which the organism is aided by some external influence. Active dispersal has been examined by Ben-Tuvia (1966), who records the migration of at least 24 species of fish from the Red Sea to the Mediterranean Sea since the opening of the Suez Canal in 1869. Similar migrations of ostracode in this area have not been observed. Menzies (1968), whose main interest was in the dispersal of fouling organisms, tested the possibility of passive dispersal of several taxonomic groups of shallow-water to intertidal marine invertebrates, both fouling and non-fouling types, by shipping along the Panama

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Canal. His work demonstrated significant survival rates for both types, and from this he suggested that fouling animals attachced to the hulls of ships might well survive such trips. Although ostracodes are non-fouling, some may possibly have achieved widespread dispersal by similar means.

During an investigation of distributions of ostracode biofacies in British Honduras (Teeter, 1966), the writer examined Recent marine sediment samples from other shallow-water areas, notably the Indian and Pacific Oceans. The results of the above studies indicated the presence of several ostracode species in common between the Caribbean and Indo-Pacific areas. Comparisons of available material with the literature yielded several additional species with widespread distributions. Table 1 records the distributions of these widespread

TABLE 1

Distribution of some Recent epidemic ostracode species

Species	Locality													
	1*	2*	3	4	5	6	7	8	9	10	11	12	13	14
Bairdia teeteri Allison and Holden	x	x									x			
Triebelina sertata Triebel	x	x				x*					x			
T. rugosa Allison and Holden	x	x									x			
Leptocythere demissa (Brady)	x	x	x*		x*	x*		x		x*				
Leptocythere inconspicua (Brady)	x	x		x*	x*		x*			x*				
Callistocythere cranekeyensis (Puri)	x	x								x*				
Tanella gracilis Kingma		x	x*			x*								
Hemicytherura cranekeyensis Puri	x	x										x		
Occultocythereis angusta Bold	x	x												x
Krithe reniformis (Brady)	x												x	
Copytus baculoides (Brady)	x								x*					
Microcythere sp. cf *M. inflexa* Mueller	x	x											x	
Neomonceratina mediterranea (Ruggieri)	x	x				x							x	

Localities: 1. British Honduras, 2. Caribbean—Gulf of Mexico, 3. East Africa, 4. Persian Gulf, 5. Phillipines, 6. Indonesia (Key, 1954a), 7. Australia, 8. New Zealand (Hornibrook, 1952), 9. Fiji, 10. Hawaii, 11. Clipperton Atoll (Allison and Holden, 1971), 12. Baja California (McKenzie and Swain, 1967), 13. Mediterranean (Müller, 1894; Ruggieri, 1953), 14. Madeira (Bold, 1963).

*Note: Specimens in columns 1 and 2 and those marked by asterisks have been examined and compared by the writer and are deposited in his personal collection. All other occurrences are based on the literature.

ostracode species and Figures 1 and 2 illustrate, for comparison, several of these species from various localities. A few of these distributions, as well as some others, have been noted elsewhere (Puri, 1960, p. 132; Bold, 1963, p. 391–392; McKenzie and Swain, 1967, p. 291; Key, 1954a, p. 361; 1954b, p. 222; Swain, 1955, p. 643; Morales, 1966, p. 64–66; Allison and Holden, 1971, p. 174–176, 179–180; Sandberg, 1964). Several dispersal mechanisms have been discussed in the literature to account for widespread distribution of some ostracode species, however, because all of these mechanisms encounter problems in explaining the distribution of the ostracodes discussed here, the purpose of this paper is to examine the possibility that their interoceanic dispersal has been accomplished passively and unknowingly by man.

DISPERSAL MECHANISMS

Because the majority of ostracodes are benthonic, including those listed in Table 1, some mechanism must be sought to explain the surprisingly widespread

distribution of these species. More than one means of dispersal is possible, as these species collectively inhabit a variety of environments from nearshore shallow brackish-water conditions to depths in excess of 30 meters and with normal marine salinities.

That ostracodes as eggs, larvae, and adult forms may be passively dispersed by such means as wind, birds, fish, water insects, and drifting algae has been indicated by Sandberg, in an excellent review (Sandberg, 1964, p. 17–23). In this review he concentrates especially on dispersal by birds, and notes that some freshwater and brackish-water ostracodes may have achieved exceptionally widespread distribution by this means. Ostracodes could be carried for long distances along migratory flyways when encased in mud clinging to the feet of shore and wading birds, the most generally accepted mode of transport, or, alternatively, when trapped in the feathers of wading birds. The encysted (double-walled) eggs of freshwater ostracodes are ideally suited to withstand dessication during such flights, and even adult and late juvenile instars have been shown to be capable of withstanding drying for periods of two weeks or more when encased in mud (Klie, 1926). As Sandberg (1964) points out, selection has favoured the evolution of dissication-resistant adaptations for those ostracodes living in relatively ephemeral freshwater environments. It is also possible that ostracodes accidentally ingested during feeding could be transported in the intestinal tracts of shore birds. In the presence of digestive acids, survival of the calcareous-shelled larval and adult forms is less likely than is that of the encysted egg.

Avian dispersal of the marine ostracode species considered in Table 1, however, is unlikely. Unlike freshwater ostracodes, the eggs of marine ostracodes are not known to withstand any dessication (Kesling, 1961, p. 19), and therefore would not survive aerial transport. Also, the ostracodes considered here live at such depths in the sea that they are unlikely to have the opportunity of becoming adhered to the feet of wading birds. Finally, the ostracodes in Table 1 are latitudinally restricted to the tropics and subtropics, covering extensive oceanic areas, and are not longitudinally restricted, as are the predominantly continental flight paths of migratory birds.

Wind and fish are unlikely agents for worldwide dispersal of marine ostracodes. Dessication of the single-walled egg of marine ostracodes would probably result in death during wind transport. Larval and adult forms, because of their larger size, are less susceptible to wind transport, but would probably also suffer the same fate as the (marine) ostracode eggs. Kornicker and Sohn (1971) have studied the survival of adult freshwater ostracodes and eggs ingested by fish. None of the adults survived ingestion, although those authors speculate that under some conditions survival may occur. Only a low percentage of the eggs ingested was found to be viable after having been voided. This author suspects that the double-walled egg of freshwater ostracodes may account for this, and that

PREPARATION AND PHOTOGRAPHIC TECHNIQUE

The specimens in Figures 1 and 2 were prepared for photography by heating, staining with green water-soluble dye, and immersing in castor oil, as described by Morkhoven (1962). The microscope used in photographing the ostracodes was a Leitz Ortholux equipped with objective lenses with built-in iris diaphragm to achieve greater depth of focus. The camera was a 35 mm. Spotmatic Pentax and the correct exposure time was determined by trial.

EXPLANATION OF FIGURE

FIGURE 1a-f. *Triebelina sertata* Triebel: a—whole carapace, right side, Br. Hond.; b—left valve, Br. Hond.; c—right valve, Oahu; d—left valve, Oahu; e—left valve, Sorong, New Guinea; f—left valve, Ram Is., New Guinea. g-l.—*Leptocythere inconspicua* (Brady): g—left valve, Br. Hond.; h—right valve, Br. Hond.; i—left valve, Oahu; j—right valve, Oahu; k—right valve, Fla. Keys; l—right valve, Great Barrier Reef, Australia. All figures ×100.

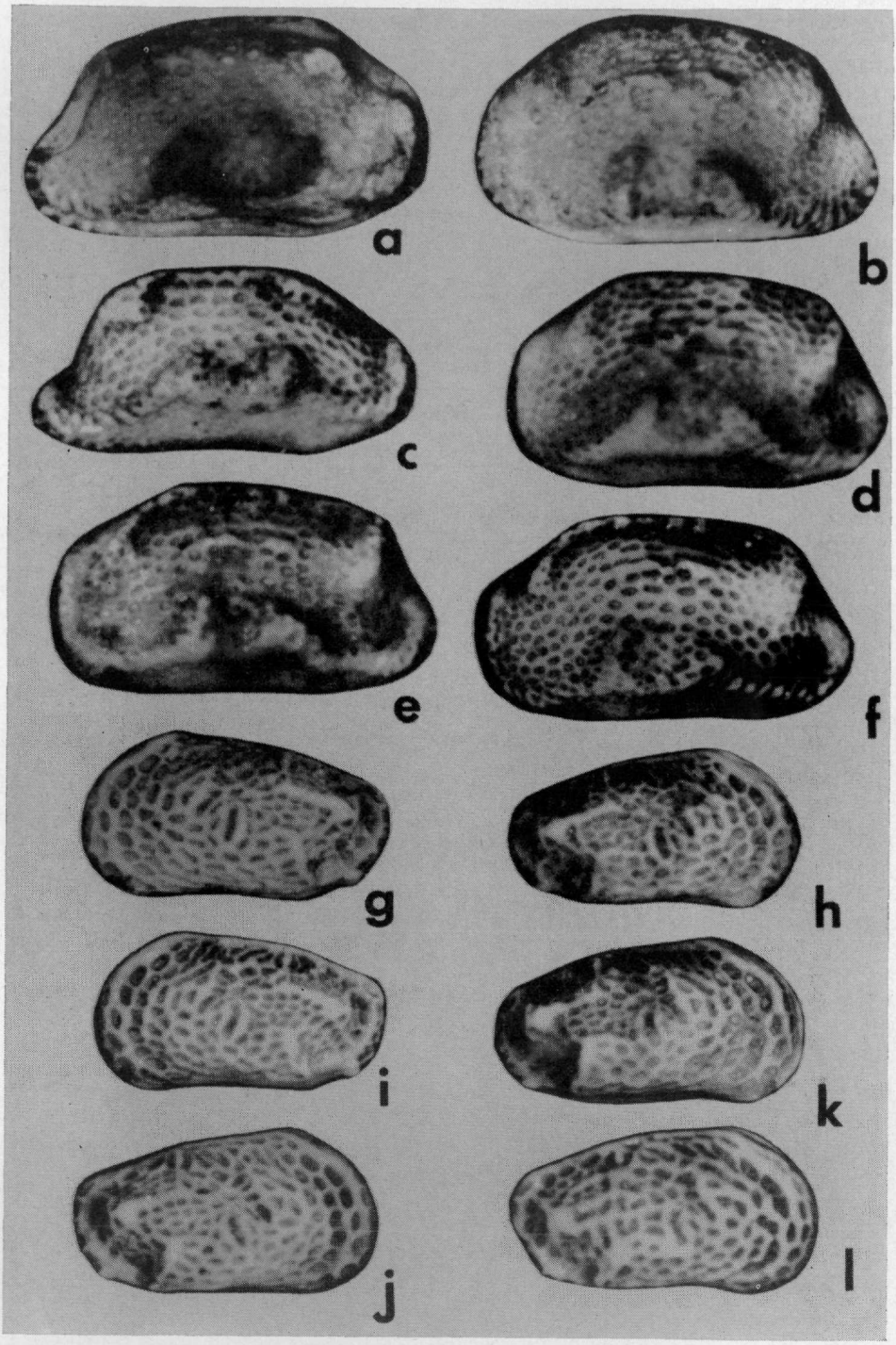

FIGURE 1

the liklihood of survival of marine ostracode eggs, with their single wall, would be correspondingly less. In the small fish (goldfish and swordtails) used by Kornicker and Sohn (1971), egestion usually took place in about two hours, thus severely limited the possibility of dispersal across any wide barrier to ostracode migration. Also, most fish inhabit rather local environments and do not roam throughout the oceans of the world.

Drifting aquatic plants may provide transport for some Ostracoda. Such a plant is the marine alga *Turbinaria*, which grows along rocky, reefy shores in the tropics. Living specimens of *Hemicytherura cranekeyensis* Puri have been observed in the one sample of this alga collected by the author in British Honduras. Fragments of *Turbinaria* often break loose and may be found floating many miles from shore. Examination by the author of the ostracode epifauna of a second type of alga, *Sargassum*, from the Florida Keys, indicates the presence of several of the species listed in Table 1. This alga, which normally grows attached to the substrate, frequently breaks free and drifts widely across the tropics at the surface of the sea. Both *Turbinaria* and *Sargassum* occur in the tropical portions of the Atlantic and Pacific Oceans. Once afloat, these algae, under the influence of surface water-currents, may either drift in climatic zones favorable for the associated tropical fauna, or enter regions too cold for the commensals' survival. Thus, successful passage for tropical ostracodes around the southern tips of Africa and South America or through the Arctic Ocean is unlikely, because of the colder water temperatures there. A much more favorable interoceanic route would be through the Suez Canal, should the hypersaline waters of the Great Bitter Lake permit the passage of commensal marine ostracodes. A cursory examination of the literature and of Recent sediment samples from the Mediterranean and the Red Sea and Western Indian Ocean revealed only one ostracode species in common, *Neomonoceratina mediterranea* (Ruggieri).

The Panama Canal offers a second interoceanic route, but here the fresh water of Gatun Lake should act as a barrier to the passage of marine ostracodes. In spite of this apparent barrier, the greater number of ostracodes listed in Table 1 as occurring in common between the Indo-Pacific Ocean and the Caribbean Sea suggests that the Panamanian route may be more frequently used than the Suez. As both routes present salinity impediments to the passage of marine ostracodes, why should the Panamanian route apparently be more popular than the Suez? It is possible that the Suez route, which connects tropical and subtropical water bodies, may present too great a climatic range for the adjustment of most ostracodes. The shorter Panamanian route, lying entirely within the tropics, may be more suitable because it traverses a much narrower latitudinal zone.

If, as suggested above, the Panamanian route is the more important of the two, how and when may the ostracode migrations have proceeded? The possibility exists that the ostracode species achieved their distribution by floating vegetation, or some other means unaided by man, prior to the rise of the Panamanian land bridge.

Knowledge of the distribution of fossil ostracodes is imperfect for the areas being considered. An extensive series of papers by Bold, from 1946 to the present, has done much to alleviate this problem in the Caribbean. Much

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EXPLANATION OF FIGURE

FIGURE 2a-g. *Leptocythere demissa* (Brady): a—left valve, Br. Hond.; b—right valve, Br. Hond.; c—left valve, Fla. Keys; d—right valve, Fla. Keys; e—left valve, Oahu; f—right valve, Oahu; g—right valve, Mozambique, East Africa. h-k.—*Callistocythere cranekeyensis* (Puri): h—left valve, Br. Hond.; i—right valve, Br. Hond.; j—left valve, Oahu; k—right valve, Oahu. 1-p.—*Tanella gracilis* Kingma: l—right valve, Fla. Keys; m—right valve, Qatar, Persian Gulf; n—right valve, Aden; o—left valve, Aden; p—right valve, Suez. All figures ×100.

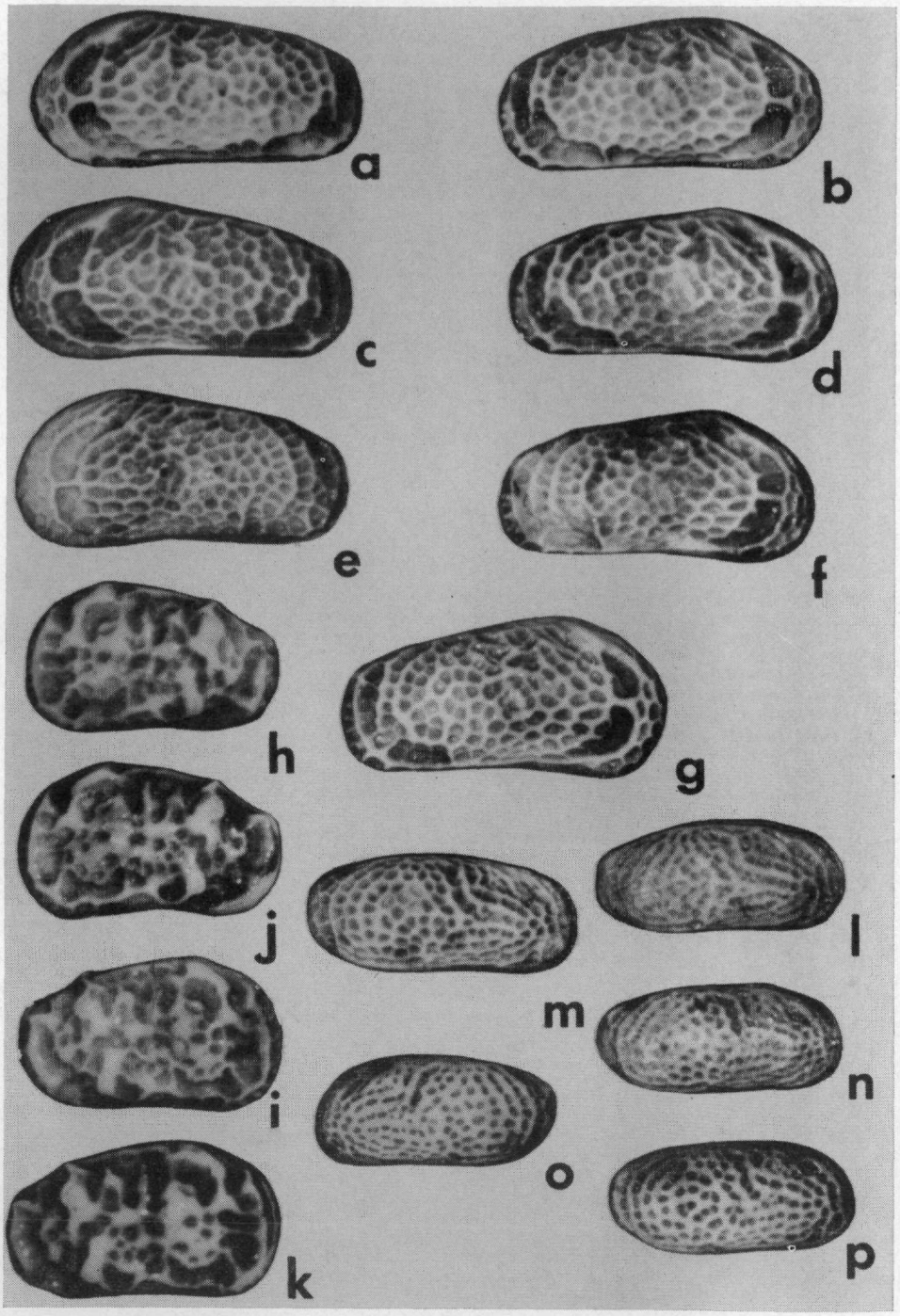

FIGURE 2

less work has been done on the areally more extensive Indo-Pacific region. In spite of this difficulty, some tentative information on ostracode migrations may still be gleaned. The distributions of those species having a known fossil record are given in Table 2. Based on these data, three species (*Triebelina sertata* Triebel, *Leptocythere demissa* (Brady), and *Tanella gracilis* Kingma) apparently originated in the Indo-Pacific, and one species (*Hemicytherura cranekeyensis* Puri) apparently originated in the Caribbean or Atlantic Coastal Plain. Holden (personal communication, 26 November 1971) has found a species of *Leptocythere*, very possibly conspecific with *L. inconspicua* (Brady), from the lower, upper, and post-Miocene of Midway Island. Lack of a fossil record of these species elsewhere suggests that their migration to other areas was accomplished relatively recently—after the rise of the Panamanian land bridge, although future work may prove the existence and migration of these and other fossil species, listed in Table 1, prior to the development of land barriers.

Recent dispersal of the widespread ostracode species may have been aided by transoceanic shipping. Ocean-going vessels frequently develop plant growth on their underwater hulls and such vegetation may harbour an extensive microfauna. Such organisms, however, probably would not survive exposure to the fresh water of Gatun Lake, or the hypersalinity of Great Bitter Lake. Alter-

TABLE 2

Fossil occurrences of epidemic ostracode species

Species	Location	Age and reference
Triebelina sertata	N. Sumatra	Lower Pliocene (Kingma, 1948)
	Seram	Quaternary (Bold, 1946)
Leptocythere demissa	New Zealand	Eocene-Recent (Hornibrook, 1952)
Tanella gracilis	Indonesia	Pleistocene (Kingma, 1948)
Hemicytherura cranekeyensis	North Carolina	Upper Miocene (personal collection)
	Florida	Plio-Pleistocene (personal collection)
	Trinidad	Lower-Upper Miocene (Bold, 1957)

natively, ballast tanks of vessels may provide a temporary refuge for marine ostracodes and their host plants during transport through the Panama Canal. Tankers and bulk carriers add considerable ballast. Chesher (1968) notes that, in preparation for passage through the Panama Canal, oil tankers commonly pump large volumes of seawater into special bilge tanks used exclusively for this purpose. The intake pipes are located near the water surface and, whereas large organisms would perish in the impeller pumps, microscopic organisms and sections of floating algae and their epifauna would very likely survive. The water ballast is expelled either upon leaving the canal or during loading at the next port of call.

The dispersal center for the ostracodes of Table 1 might appear to be the Caribbean; however, these data more likely represent the bias of greater sampling density from this region. Continued sampling in other tropical areas may well extend the ranges of these species. As most of the ostracodes in Table 1 are apparently restricted in time to the Recent, it will perhaps be impossible to determine the area from which most of the species have dispersed. For the four or five species that have a known fossil record (see Table 2), all but one appears to have originated in, and dispersed from, the Indo-Pacific region. In view of the apparent dispersal of those species having a fossil record, it is interesting that Chesher (1968) notes that the greatest traffic in empty ships, requiring water ballast, is from west to east across Panama.

CONCLUSIONS

The widespread distribution of several species of marine, tropical benthonic ostracodes requires a dispersal mechanism. Dispersal by birds is unlikely because of the lack of coincidence between migratory flyways and ostracode distributions discussed here, inability of marine ostracode eggs to withstand dessication, and the occurrence of ostracodes at water depths greater than those frequented by wading shore birds. Wind dispersal of marine ostracode eggs is also unlikely because of the eggs' inability to withstand dessication. Dispersal of marine ostracodes ingested by fish is unlikely because of probable digestion within the fish's stomach. In addition, the duration between ingestion and egestion is probably far shorter than the time required for a fish to cross an oceanic barrier to shallow-water marine ostracodes. Also, most fish inhabit rather local environments and do not roam the world's oceans.

The association of several ostracode species with floating algae suggests that such plants, especially in the equatorial currents and countercurrent, may provide transoceanic dispersal. Colder temperatures encountered by tropical algae drifting into the higher latitudes would probably cause the death of associated ostracodes, thus preventing interoceanic dispersal via such routes. Although ostracodes may live in vegetation attached to the hulls of ships and thus accomplish trnasoceanic dispersal, it is unlikely that they would survive the fresh waters of the Panama Canal or the hypersaline waters of the Suez. Man may inadvertently contribute to the interoceanic distribution of these ostracodes through the Panama Canal by the inclusion of floating algae in water taken into bilge tanks during ballasting. Based on the few species considered in this study that have a known fossil record, most appear to have dispersed from the Indo-Pacific area.

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REFERENCES CITED

Allison, E. C., and **J. C. Holden.** 1971. Recent ostracodes from Clipperton Island, eastern tropical Pacific. San Diego Soc. Nat. Hist. Trans. 16: 165–214.

Ben-Tuvia, A. 1966. Red Sea fishes recently found in the Mediterranean. Copeia 2: 254–275.

Boffey, P. M. 1971. Sea-level canal: how the Academy's voice was muted. Science 171: 355–358.

Bold, W. A. van den. 1946. Contribution to the study of Ostracoda with special reference to the Tertiary and Cretaceous microfauna of the Caribbean region. Diss., Univ. Utrecht. 167 p.

——— 1957. Oligo-Miocene Ostracoda from southern Trinidad. Micropaleont. 3: 231–254.

——— 1963. Upper Miocene and Pliocene Ostracoda from Trinidad. Micropaleont. 9: 361–424.

Chesher, R. H. 1968. Transport of marine plankton through the Panama Canal. Limnol. and Oceanog. 13: 387–388.

Hornibrook, N. de B. 1952. Tertiary and Recent marine Ostracoda of New Zealand, their origin, affinities and distribution. N. Z. Geol. Surv. Palaeont. Bull. 18. 82 p.

Kesling, R. V. 1961. Reproduction of Ostracoda. p. 17–19. *In* Moore, R. C., ed. Treatise on Invertebrate Paleontology, Part Q, Arthropoda 3, Crustacea, Ostracoda. Univ. Kansas Press. 442 p.

Key, A. J. 1954a. Some Recent Ostracoda of Manila (Philippines). Kon. Ned. Akad. Wetensch. Ser. B. 57: 351–363.

——— 1954b. Identification and description of species. p. 218–245. *In* Andel, T. van, and H. Postma. Recent Sediments of the Gulf of Paria. Reports of Orinoco shelf expedition. Verh. Kon. Ned. Akad. Wetensch. Natuurk. Ser. 1, pt. 20, no. 5. 245 p.

Kingma, J. T. 1948. Contributions to the knowledge of the young Caenozoic Ostracoda from the Malayan region. Thesis, Univ. Utrecht. 119 p.
Klie, W. 1926. Ostracoda, Muschelkrebse. *In* Schulze, P. Biologie der Tiere Deutschlands. 22: 1–56.
Kornicker, L. S., and **I. G. Sohn.** 1971. Viability of ostracode eggs egested by fish and effect of digestive fluids on ostracode shells—ecologic and paleoecologic implications. p. 125–135. *In* Oertli, H. J., ed. Colloque sur la Paléoécologie des Ostracodes. Bull. Centre Rech. Pau–SNPA. 5. 953 p.
McKenzie, K. G., and **F. M. Swain.** 1967. Recent Ostracoda from Scammon Lagoon, Baja California. J. Paleont. 41: 281–305.
Menzies, R. J. 1968. Transport of marine life between oceans through the Panama Canal. Nature 220: 802–803.
Morales, G. A. 1966. Ecology, distribution, and taxonomy of Recent Ostracoda of the Laguna de Terminos, Campeche, Mexico. Univ. Nac. Aut. de Mexico, Inst. de Geol. 81. 103 p.
Morkhoven, F. P. C. M. van. 1962. Post Paleozoic Ostracoda, their Morphology, Taxonomy and Economic Use. Volume 1: General. Elsevier Pub. Co., New York. 204 p.
Müller, G. W. 1894. Die Ostracoden des Golfes von Neapel und der angrenzenden Meeresabschnitte. Naples Sta. Zool. Fauna Flora Golfes Neapel. Mon. 31. 404 p.
Puri, H. S. 1960. Recent Ostracoda from the west coast of Florida. Gulf Coast Assoc. Geol. Soc. Trans. 10: 107–149.
Rubinoff, I. 1968. Central American sea-level canal: possible biological effects. Science 161: 857–861.
Ruggieri, G. 1953. Ostracodi del genere *Paijenborchella* viventi nel Mediterraneo. Atti. Soc. Ital. Sci. Nat. 92: 3–7.
Sandberg, P. A. 1964. The ostracode genus *Cyprideis* in the Americas. Stockholm Contrib. Geol. 12. 178 p.
Swain, F. M. 1955. Ostracoda of San Antonio Bay, Texas. J. Paleont. 29: 561–646.
Teeter, J. W. 1966. The distribution of Recent marine ostracodes from British Honduras. Unpub. Ph.D. diss., Rice Univ. 212 p.

Biological Rhythms in Human and Animal Physiology. *Gay Gaer Luce.* Dover Publications, Inc. New York, 1972. (paperback reprint of Public Health Service Publication No. 2088, *Biological Rhythms in Psychiatry and Medicine.* Nat. Inst. of Mental Health 1970). vii+183 p. $2.50.

Everything from sunspots to psychosomatic illness as it related to biological rhythms is mentioned in this book. It is impossible to tell in capsule form what this book is about other than to repeat the title.

The publisher's note states that this "is an unabridged and unaltered republication of . . . [a] report . . . prepared for the . . . National Institute of Mental Health." Perhaps the word "report" best describes this volume; it is certainly not a textbook and probably could not be considered a review article in the usual sense. It lacks a preface in which the author could tell us for what audience and purpose it was intended.

The very detailed Table of Contents divides the 152 pages of text into twelve chapters with 144 sub-headings. Under each sub-heading there are three to ten thumbnail sketches of research papers related to the subject named in the heading.

These sketches individually and in small groups make very interesting and easy reading for those who wish to be casually informed or for someone who wants a quick over-view of the results and conclusions of a particular scientific paper. Presumably the 31 pages of bibliography at the end (41 citations per page) contain all of the papers referred to, by author's name only, in the text. This end section is a combination of References and Index and, by virtue of being combined, does only a mediocre job as either. The citations are divided into 22 separate alphabetical listings, each list containing papers on a similar subject. Within the list, the papers are listed alphabetically by author's names. These 22 subject lists comprise an inadequate Index of sorts. If one wishes to look at the original paper referred to in the text by the author's name, one might have to look through all 22 lists before finding the citation to the paper by that particular author. If one sees an author or title in the References that he wishes to read about in the text, it is necessary to read the entire text to find it. No text page numbers are given in this Index-Bibliography.

In summary, the text is well written, with the right amount of balance between detail and conciseness. It flows well within subjects, but jumps abruptly from one aspect of biological rhythms to another. The bibliography is very extensive and the subdividing by subject areas is helpful in using this section by itself. However, the lack of cross-referencing between bibliography and text is regrettable. This book should be of value both to the scientist working in the area of biological rhythms as a bibliographical compilation and review and of interest to the educated layman.

DAVID H. NOYES